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1. Your reference — P35035GB/PH

2. Patent application number *(The Patent Office will fill in this part)* — 17 DEC 2002 — 0229381.9

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*

   Switched Reluctance Drives Limited
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   Harrogate, North Yorkshire, HG3 1PR
   England

   07010713001
   Patents ADP number *(if you know it)*

   If the applicant is a corporate body, give the country/state of its incorporation — England

4. Title of the invention

   Electro-mechanical transmission systems

5. Name of your agent *(if you have one)*

   "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*

   Kilburn & Strode
   20 Red Lion Street
   London
   WC1R 4PJ

   Patents ADP number *(if you know it)* — 125001

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Claim *(s)*	4
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11. I/We request the grant of a patent on the basis of this application.

Signature Withers & Rogers Date 17/12/2002

12. Name and daytime telephone number of person to contact in the United Kingdom

Hale, Peter
Tel: 020 7539 4200

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ELECTRO-MECHANICAL TRANSMISSION SYSTEMS

The present invention relates to a method of operating electro-mechanical transmission systems.

A known form of electro-mechanical transmission system comprises two compounded epicyclic gearsets, having an input shaft driven by a prime mover and connected to one gear element of one gearset, an output shaft providing output torque and connected to one gear element of the other gearset, two electrical machines, the rotors of which are connected to respective gear elements of the two gearsets and each of which is able to operate either as a motor or a generator and the stators of which are connected together via a controller arranged to selectively control the flow of electrical power between the machines.

Such transmission systems are of continuously variable transmission ratio and are preferably of single regime type, that is to say they can provide all the necessary gear ratios without it being necessary to provide a clutch or the like to enable switching over to a further transmission system to obtain a portion of the desired range of transmission ratios.

An epicyclic gearset typically comprises a sun wheel in mesh with a plurality of planet wheels, which are rotatably mounted on a common carrier and are in mesh with an annulus wheel. However, it is possible under certain circumstances for an epicyclic gearset to have only two of these gear elements, whereby one of the sun wheel, planet wheels and annulus wheel is omitted.

A transmission system of the type referred to above is disclosed in WO-A-01/94142. This known transmission system comprises an input shaft connected to the planet carrier of the first gearset, which is also connected to the annulus wheel of the second gearset, and an output shaft connected to the planet carrier of the second gearset. The sun wheel of the first gearset is connected to the sun wheel of the second gearset. The rotors of the first and second electrical machines are respectively connected to the annulus wheel of the first gearset and the sun wheel of the second gearset. The electrical connections of the two stators are connected together via a control system.

In use, one of the electrical machines generally acts as a generator and transfers electrical power to the other electrical machine which acts as a motor. A proportion of the power transmitted by the transmission system is thus transmitted mechanically whilst a further varying proportion, which is typically up to about one third of the total, is transmitted electrically. Varying the electrical power transmitted between the two electrical machines, which may simply be achieved by varying the torque by means of the controller, which forms part of the control system, of one of the electrical machines, results in the torque available at the output varying at constant speed of the input.

The maximum electrical power transferred between the two electrical machines varies as the output speed varies and at least usually reaches zero at two different output speeds. When this power is zero, one of the electrical machines is stationary. In the known transmission the power transmitted between the two electrical machines is zero at a first finite output speed, i.e. an output speed greater than zero, and at a second higher output speed, whereby power is

transmitted between the electrical machines at zero output speed. This means that the transmission with which the present invention is concerned provides a "geared neutral", i.e. the output may be arranged to be stationary when the input is rotating.

The known transmission may have many different applications which are required to be driven by a source of motive power In the art the source of motive power is typically referred to as a prime mover. In particular the transmission system is useful as the main propulsion transmission for a motor vehicle. A rechargeable battery may be provided to enable the vehicle to be of hybrid type, that is to say the electric battery may supply electric power to one of the electrical machines to increase the torque on the output shaft. At those times when excess power is available, electric power may be transmitted from one of the electrical machines to the battery to recharge it.

One of the disadvantages of transmission systems of the type disclosed in WO-A-01/94142 is that they do not accelerate from rest as rapidly as is sometimes desirable, depending on the inertia of the load to which they are connected. As mentioned above, the transmission has a geared neutral and at zero output speed one electrical machine acts as a generator and its power is supplied to the other electrical machine, which is driven as a motor. If it is desired to accelerate from rest, the maximum possible torque may be required at the output shaft which is at zero output speed so that no work is performed. If one ignores the slight inefficiencies of the two electrical machines and the various meshing gearwheels, if no work is done at the output shaft, then no power is supplied to the input shaft by the vehicle engine. Accordingly, the torque applied to the output shaft is simply the sum of the torques on the two electrical machines.

This means either that the vehicle will accelerate relatively slowly or that the electrical machines must have relatively high rated powers, in which event they will be unacceptably large, heavy and expensive. This problem can of course be alleviated to an extent by utilising the hybrid function of the vehicle, that is to say operating the controller to supply electric power from the battery to that electrical machine which is acting as a motor. This will increase the torque at that electrical machine and thus the torque on the output shaft. However, this increase is not very large and can only be for a relatively short period of time unless both the battery and the electrical machines are of a size which will make the transmission unacceptably heavy and expensive.

It is, therefore, an object of the invention to provide a method of increasing the torque applied to the output shaft, particularly when accelerating the output shaft of an electro-mechanical transmission system of the type referred to.

According to a first aspect of the invention there is provided an electro-mechanical transmission system, comprising two compounded epicyclic gearsets, one gear element of one gearset being connected to an input shaft and one gear element of the other gearset being connected to an output shaft, the input shaft being connected to a prime mover, the rotors of two electric machines being connected to respective gear elements of the two gearsets, the electrical connections of the stators of which machines are connected together via a controller arranged to selectively control the flow of electrical power between the machines and an energy receiver, the controller being operable to direct at least a proportion of electric power from that machine which is operating as a generator to the energy receiver.

The present invention is defined in the accompanying independent claims. Some preferred features are recited in the dependent claim.

According to the invention it is possible to increase the torque applied to the output shaft for a given prime mover and transmission system without having to modify the machinery.

It has been found by the inventor that the torque increase can be realised by dissipating some of the power from the prime mover instead of making it available as motive power.

According to one aspect of the present invention the method includes increasing the torque available at the output shaft by directing electric power from at least one of the machines to an electrical load comprising a dump resistor.

In practice, electrical power is likely to be taken only from that machine which is operating as a generator. However, it would be possible to cause both machines to operate as generators and to take electrical power from both of them.

According to a further aspect of the invention the method includes increasing the torque available at the output shaft by mechanically braking at least one of the electrical machines.

According to a further aspect of the invention the method includes increasing the torque available at the output shaft by causing one or both of the electrical machines to operate less efficiently. If, as is preferred, the two electrical

machines are of switched reluctance type, this may comprise altering the timing of excitation of one or both machines so that it operates at an efficiency substantially less than the maximum value that may be achieved and thus operates in a manner similar to using a dump resistor.

According to yet a further aspect of the present invention the method includes increasing the torque available at the output shaft by directing electric power from at least one of the machines, preferably again that machine which is operating as a generator, to an electrical load comprising a rechargeable electric battery.

According to a yet further aspect of the present invention there is provided a method of operating an electro-mechanical transmission system of the type comprising two compounded epicyclic gearsets, having an input shaft driven by a prime mover and connected to one gear element of one gearset, an output shaft providing output torque and connected to one gear element of the other gearset, two electrical machines, the rotors of which are connected to respective gear elements of the two gearsets and each of which is able to operate either as a motor or a generator, a third electrical machine, operable as a motor, and having its output shaft connected to one of the input and output shafts of the transmission system, all three machines having the electrical connections of the stators of all three electrical machines being connected together via a controller arranged to selectively control the flow of electrical power between the machines, which method includes increasing the torque available at the output shaft by directing electric power from at least one of the machines, preferably that machine which is operating as a generator, to the third electrical machine.

The method will find particular application when the output shaft is rotating relatively slowly and is of particular value when accelerating the output shaft from a rest condition, in which the transmission system is in a geared neutral condition, in which the two electrical machines act as a generator and a motor, respectively.

Expressed in its broadest sense the invention embraces increasing the torque available at the output by extracting energy, in electrical or mechanical form, from the transmission system. Thus according to yet a further aspect of the present invention the method includes monitoring a signal indicative of the level of torque required at the output shaft and extracting energy in mechanical or electrical form from the transmission system when the said signal exceeds a predetermined value.

The method of the present invention is thus counter-intuitive and effectively the opposite of what is disclosed in the prior document referred to above in that at the time that maximum torque is required at the output shaft, additional power is not introduced into the transmission system from a battery or the like but instead power is removed from the transmission system and this is found surprisingly to result in an increase in the output torque.

Clearly, some aspects of the method of the invention will reduce the overall efficiency of the transmission system. A practical system might therefore avoid dumping energy except when large output torques are required, thereby only invoking the system when needed to boost output torque.. When the system is used to boost torque the diverted energy may be used for some other auxiliary system or stored for later use.

Thus in the method of the present invention, when, for example, a vehicle incorporating a transmission system of the type referred to is stationary and the vehicle engine is idling, the controller is set so that one of the electrical machines is generating only a small amount of electrical power and this power is transmitted to the other electrical machine. The sum of the torques at the two electrical machines is very small and only this very small torque acts on the output shaft. Movement of the vehicle is prevented by frictional losses and/or application of the vehicle brake. If gentle acceleration is required, the controller is operated, in practice, by the engine management system which is nowadays commonly provided on motor vehicles and of which the controller will in practice form a part, to increase the electrical power transmitted from the generator to the motor. The torques of both the motor and generator will increase and the torque acting on the output shaft will be the sum of the torques at the motor and the generator and the torque applied by the engine to the input shaft to compensate for the mechanical and electrical losses within the transmission system, which are in practice inevitable. The controller is operated to produce whatever level of torque on the output shaft is desired. As the vehicle starts to move, an increasing amount of work is performed at the output shaft and an increasing proportion of the torque on the output shaft is derived from the vehicle engine. If, however, rapid acceleration is required, the controller is operated to increase the electrical power transmitted from the generator and at the same time energy is removed from the system, either mechanically, by braking some element of the system, or electrically, e.g. to a dump resistor. The power removed must be supplied by the engine which now adds torque into the system. The torque at the output is the sum of all the torques and therefore increases. Since the engine is running at low speed, it has

a great deal of power available and it supplies to the input shaft an amount of power equal to the sum of that removed and the amount accounted for by mechanical and electrical losses. The torque applied to the output shaft is thus increased by not only any increase in the torques at the motor and the generator but also the increase in torque on the input shaft.

The method of the invention is used similarly to increase the output torque when the vehicle or the like is already moving relatively slowly. However, in this case, instead of increasing the power supplied to the motor and removing power from the system, a proportion of the power supplied to the motor may be diverted, e.g. to a dump resistor. In this case, the torque at the motor will decrease, and the power removed from the system will be additionally provided by the input shaft. However, since the input shaft will typically rotate very much more slowly than the input shaft, the torque increase on the input shaft will be substantially more than the torque reduction at the motor so that the sum of the torques, i.e. the torque available at the output shaft, is still significantly increased.

Accordingly, the load may be accelerated from rest more rapidly than was previously possible. Alternatively, or expressed in other words, for a given maximum rate of acceleration from rest, the two electrical machines may be smaller, lighter and cheaper than was previously the case.

The invention also embraces an electro-mechanical transmission system comprising two compounded epicyclic gearsets, having an input shaft adapted to be driven by a prime mover and connected to one gear element of one gearset, an output shaft which, in use, provides output torque and is connected

to one gear element of the other gearset, two electrical machines, the rotors of which are connected to respective gear elements of the two gearsets and each of which is able to operate either as a motor or a generator and the stators of which are connected together via a controller arranged to selectively control the flow of electrical power between the machines, and a mechanical brake arranged to brake at least one of the electrical machines.

In a further aspect of the invention, the transmission system does not include a brake but includes a third electrical, which is operable as a motor and whose output shaft is connected to one of the input and output shafts and which is connected to at least one of the said two electrical machines to be electrically powered thereby.

In a final aspect of the invention, the transmission system includes a sensor arranged to produce a signal indicative of the level of torque required at the output shaft, means for monitoring the said signal and means controlled by the monitoring means for extracting power in mechanical or electrical form from the transmission system when the said signal exceeds a predetermined value.

Further features and details of the invention will be apparent from the following description of specific embodiments which are given by way of example with reference to the accompanying drawings in which:

Figure 1 is a schematic view of an electro-mechanical transmission system, which may be operated in accordance with the invention; and

Figure 2 is a flowchart of a control scheme by which the invention can be implemented using the system of Figure 1.

The transmission system shown in Figure 1 comprises an outer housing 10 accommodating two epicyclic gearsets 12 and 14. The first gearset 12 comprises a first sun wheel 16, which is fixedly carried by a shaft 18, which is mounted to rotate with respect to the housing 10 by bearings 20. A first carrier 22 which constitutes a flywheel and is connected to an input shaft 23 carries a number, in this case three, of equispaced shafts 24, which carry respective first planet wheels 26. The first planet wheels 26 are in mesh with the first sun wheel 16 and with an internally toothed first annulus wheel 28.

The first carrier 22 is connected via a radial flange 30 to the annulus wheel 32 of the second gearset. The second annulus wheel 32 is in mesh with a plurality of second planet wheels 34 carried by a second carrier 38. The planet wheels 34 are also in mesh with a second sun wheel 36 fixedly carried by the shaft 18. The second carrier 38 includes an externally toothed portion 40 which is in mesh with a gearwheel 42 connected to the output shaft 43.

The transmission system includes first and second electrical machines, which are capable of acting as both a motor and a generator. The machines are in this case of brushless and, specifically, switched reluctance type as described in the paper "The Characteristics, Design and Applications of Switched Reluctance Motors and Drives" by Dr. J. M. Stephenson and Dr. R. J. Blake as presented at PCIM 93, Nurnberg, Germany, June 21-24 1993 which is incorporated herein by reference. However, any type of machine could be used that can act as a motor or a generator. The machines include respective first and second stators 44 and 46 which are fixed to the housing 10. The first stator 44 is sealed with respect to the flywheel 22 by means of an oil seal 48 and a similar oil seal 50 is

provided between the output shaft and the outer housing. The first machine also includes a first rotor 52, which is connected to rotate with the first annulus wheel 28. The second machine includes a second rotor 54, which is connected to rotate with the shaft 18 and thus with the two sun wheels 16, 36.

As discussed in the Stephenson/Blake paper, the supply of electrical energy to/from the stator of each machine is by means of power rails known as the "dc link".

The stator connections on the two stators 44, 46 are connected via respective controllers 56, 58 of known type, which form part of an overall control system, to a common dc link shown schematically as line 60. The controllers are connected, in use, to e.g. the engine management system of the vehicle in which the transmission is installed. They are used in known manner to control the electrical machines and the voltage applied to the bus bar 60 by that machine which is acting as a generator and thus to control the electrical power that is transferred between the two machines. This control is the means by which the output speed and thus the transmission ratio of the transmission system are varied in response to commands by the user, e.g. by the application of pressure to the brake or accelerator pedals. The bus bar 60 is also connected to a further controller 62, which is also connected to a dump resistor 64.

Figure 2 shows a basic flowchart for the algorithm contained in the controller 62 of one embodiment of the invention. A signal is received on line 70 which is representative of the torque required on the output shaft 43. For a system with a closed-loop torque control, this signal could correspond to the torque error based on a comparison of torque on the output shaft and torque demanded

according to conventional techniques. For a system with open-loop torque control, this could represent the torque demand set by the user, e.g. in a vehicle drive, it could represent the position of an accelerator pedal. As such, it is an output demand that could be indicative of a desired speed, or even acceleration, as much as torque itself.

At box 72, the torque signal is compared with a predetermined torque level. As explained above, the invention is best put into practice when the torque requirement cannot be met by conventional operation of the drive, i.e. when the required torque is above a known threshold. Although it could be used at lower torques, it inevitably reduces the efficiency of the drive, so it is preferable to reserve it for those torques which are above the normal range for the given system.

A signal representing the speed of the output shaft 43 is provided on line 74. In a vehicle, for example, this would correspond to road speed. At box 76 the speed signal is compared with a predetermined speed level. As explained above, it is in the lower speed range of the transmission that the power source connected to the input shaft 23 will have more power available than the transmission can translate to the output shaft.

If both the tests in boxes 72 and 76 yield a positive outcome, then control passes to box 77 where the controller responds by diverting energy from the dc link, in one of the ways described above. In the event that a lower torque is required, or the speed of the output shaft has risen above the predetermined level, control passes to box 78 where conventional operation of the transmission system is invoked.

It will be appreciated by those skilled in the art that a variety of refinements can be made to the order and content of the algorithm described in Figure 2. For example, the transition into and out of diverting energy to boost the torque according to the invention can be made gradual with respect to time to avoid sudden changes of output torque. This can be achieved in a variety of known ways using control algorithms such as proportional-plus-integral (P+I) control.

In use, the electrical power transmitted between the two electrical machines will vary with the power applied to the input shaft. At maximum rated power, the output speed cannot be zero and has a minimum value at a speed at which the power transferred between the electrical machines is at a first maximum. As the output speed increases, the electrical power transferred decreases until a first node point is reached at which the power transferred is zero. As the output speed continues to increase, the electrical power transferred progressively increases again but in the opposite direction, indicating that the two machines which were previously acting as a motor and a generator are now acting as a generator and a motor respectively. As the output speed continues to increase, the power transferred again reaches a second maximum and then decreases to zero again at a further node point. The power flow again reverses direction and rises to a further maximum. The remainder of the input power is of course transmitted mechanically through the gearwheels and not electrically. The so-called Node Span Ratio, which is the ratio of the output speeds at the two node points, is preferably in excess of 2 or 2.5 or even 3. As the input power decreases, the value of the maximum achievable range of transmission ratios increases dramatically, though the node span ratio remains substantially constant.

In use, the input shaft of the transmission system would typically be connected to an automotive engine or other prime mover and the output shaft will be connected to a pair of driven wheels of a vehicle via a differential or the like, or to some other torque receiving device. The transmission system has numerous different applications.

If the transmission system is in the geared neutral condition and it is desired to accelerate rapidly, the controllers 56 and 58 are operated to substantially increase the power developed by that electrical machine which is operating as a generator and the controller 62 is operated simultaneously to dump power in the dump resistor 64. The torque acting on the input shaft 23 will increase to a value sufficient to compensate for the power transmitted to the dump resistor 64. The torque applied to the output shaft will be the sum of the torques on the two motor/generators and the torque on the input shaft. The transmission of electrical power to the dump resistor is desirable principally when a high rate of acceleration is required and then primarily only at zero and low output speeds.

In the preferred embodiment, a sensor (not shown) is provided which produces the signal on line 70 indicative of the torque required at the output shaft. When the transmission system is fitted into a motor vehicle, this sensor may conveniently respond to the position of the accelerator pedal. This signal is monitored by the control system and only when its magnitude exceeds a predetermined level, thus indicating that a high level of torque is required at the output shaft, is the controller 62 operated to transmit power to the dump resistor 64.

CLAIMS

1. An electro-mechanical transmission system, comprising two compounded epicyclic gearsets, one gear element of one gearset being connected to an input shaft and one gear element of the other gearset being connected to an output shaft, the input shaft being connected to a prime mover, the rotors of two electric machines being connected to respective gear elements of the two gearsets, the electrical connections of the stators of which machines are connected together via a controller arranged to selectively control the flow of electrical power between the machines and an energy receiver, the controller being operable to direct at least a proportion of electrical power from that machine which is operating as a generator to the energy receiver, thereby increasing the torque applied to the output shaft.

2. A system as claimed in claim 1 in which the electrical power from the machine acting as a generator is diverted from the other machine to the energy receiver.

3. A system as claimed in claim 1 or 2 in which the control means are operable to compare a signal indicative of demanded torque with a predetermined threshold and to direct the at least a proportion of the electrical power to the energy receiver if the condition that the threshold is exceeded is satisfied.

4. A system as claimed in claim 1, 2 or 3 in which the control means are operable to compare a signal indicative of the speed of the output shaft with a predetermined threshold and to direct at least a proportion of the electric power to the energy receiver if the condition that the signal is below a predetermined threshold is satisfied.

5. A system as claimed in claim 4, when dependent on claim 3, in which the at least a proportion of the electrical power is directed to the energy receiver if both conditions are satisfied.

6. A system as claimed in claim 3, 4 or 5 in which a transition to directing the at least a proportion of the electrical power is governed by a control algorithm, for example proportional-plus-integral action.

7. A method of operating an electro-mechanical transmission system of the type comprising two compounded epicyclic gearsets, having an input shaft

driven by a prime mover and connected to one gear element of one gearset, an output shaft providing output torque and connected to one gear element of the other gearset, two electrical machines, the rotors of which are connected to respective gear elements of the two gearsets and each of which is able to operate either as a motor or a generator and the stators of which are connected together via a controller arranged to selectively control the flow of electrical power between the machines, which method includes increasing the torque available at the output shaft by directing electric power from at least one of the machines to an electrical load comprising a dump resistor.

8. A method of operating an electro-mechanical transmission system of the type comprising two compounded epicyclic gearsets, having an input shaft driven by a prime mover and connected to one gear element of one gearset, an output shaft providing output torque and connected to one gear element of the other gearset, two electrical machines, the rotors of which are connected to respective gear elements of the two gearsets and each of which is able to operate either as a motor or a generator and the stators of which are connected together via a controller arranged to selectively control the flow of electrical power between the machines, which method includes increasing the torque available at the input shaft by mechanically braking at least one of the electrical machines.

9. A method as claimed in claim 8, in which only that electrical machine which is operating as a generator is braked.10. A method of operating an electro-mechanical transmission system of the type comprising two compounded epicyclic gearsets, having an input shaft driven by a prime mover and connected to one gear element of one gearset, an output shaft providing output torque and connected to one gear element of the other gearset, two electrical machines, the rotors of which are connected to respective gear elements of the two gearsets and each of which is able to operate either as a motor or a generator and the stators of which are connected together via a controller arranged to selectively control the flow of electrical power between the machines, which method includes increasing the torque available at the output shaft by causing one or both of the electrical machines to operate less efficiently.

11. A method of operating an electro-mechanical transmission system of the type comprising two compounded epicyclic gearsets, having an input shaft driven by a prime mover and connected to one gear element of one gearset, an output shaft providing output torque and connected to one gear element of the other gearset, two electrical machines, the rotors of which are connected to

respective gear elements of the two gearsets and each of which is able to operate either as a motor or a generator, a third electrical machine, operable as a motor, and having its output shaft connected to one of the input and output shafts of the transmission system, all three machines having the electrical connections of the stators of all three electrical machines being connected together via a controller arranged to selectively control the flow of electrical power between the machines, which method includes increasing the torque available at the output shaft by directing electric power from at least one of the machines which is operating as a generator to the third electrical machine.

12. A method of operating an electro-mechanical transmission system of the type comprising two compounded epicyclic gearsets, having an input shaft driven by a prime mover and connected to one gear element of one gearset, an output shaft providing output torque and connected to one gear element of the other gearset, two electrical machines, the rotors of which are connected to respective gear elements of the two gearsets and each of which is able to operate either as a motor or a generator and the stators of which are connected together via a controller arranged to selectively control the flow of electrical power between the machines, which method includes increasing the torque available at the output shaft by directing electric power from at least one of the machines which is operating as a generator to an electrical load comprising a rechargeable electric battery.

13. A method of operating an electro-mechanical transmission system of the type comprising two compounded epicyclic gearsets, having an input shaft driven by a prime mover and connected to one gear element of one gearset, an output shaft providing output torque and connected to one gear element of the other gearset, two electrical machines, the rotors of which are connected to respective gear elements of the two gearsets and each of which is able to operate either as a motor or a generator and the stators of which are connected together via a controller arranged to selectively control the flow of electrical power between the machines, which method includes monitoring a signal indicative of the level of torque required at the output shaft and extracting energy in mechanical or electrical form from the transmission system when the said signal exceeds a predetermined value.

14. A method as claimed in any one of the preceding claims which includes accelerating the output shaft from a rest condition, in which the transmission system is in a geared neutral condition, in which the two electrical machines act as a generator and a motor, respectively.

15. An electro-mechanical transmission system comprising two compounded epicyclic gearsets, having an input shaft adapted to be driven by a prime mover and connected to one gear element of one gearset, an output shaft which, in use, provides output torque and is connected to one gear element of the other gearset, two electrical machines, the rotors of which are connected to respective gear elements of the two gearsets and each of which is able to operate either as a motor or a generator and the stators of which are connected together via a controller arranged to selectively control the flow of electrical power between the machines, and a mechanical brake arranged to brake at least one of the electrical machines.

16. An electro-mechanical transmission system comprising two compounded epicyclic gearsets, having an input shaft adapted to be driven by a prime mover and connected to one gear element of one gearset, an output shaft which, in use, provides output torque and is connected to one gear element of the other gearset, two electrical machines, the rotors of which are connected to respective gear elements of the two gearsets and each of which is able to operate either as a motor or a generator and the stators of which are connected together via a controller arranged to selectively control the flow of electrical power between the machines and a third electrical machine, which is operable as a motor and whose output shaft is connected to one of the input and output shafts and which is connected to at least one of the said two electrical machines to be electrically powered thereby.

17. An electro-mechanical transmission system comprising two compounded epicyclic gearsets, having an input shaft adapted to be driven by a prime mover and connected to one gear element of one gearset, an output shaft which, in use, provides output torque and is connected to one gear element of the other gearset, two electrical machines, the rotors of which are connected to respective gear elements of the two gearsets and each of which is able to operate either as a motor or a generator and the stators of which are connected together via a controller arranged to selectively control the flow of electrical power between the machines, a sensor arranged to produce a signal indicative of the level of torque required at the output shaft, means for monitoring the said signal and means controlled by the monitoring means for extracting power in mechanical or electrical form from the transmission system when the said signal exceeds a predetermined value.

Abstract

Electro-Mechanical Transmission Systems

An electro-mechanical transmission system, driven by a prime mover, includes two epicyclic gearsets connected between input and output shafts, and two switched reluctance machines having their rotors connected to respective elements of the two gearsets. The torque on the output shaft is boosted by a controller which dumps energy from the system when one of the machines is acting as a generator and the other as a motor.

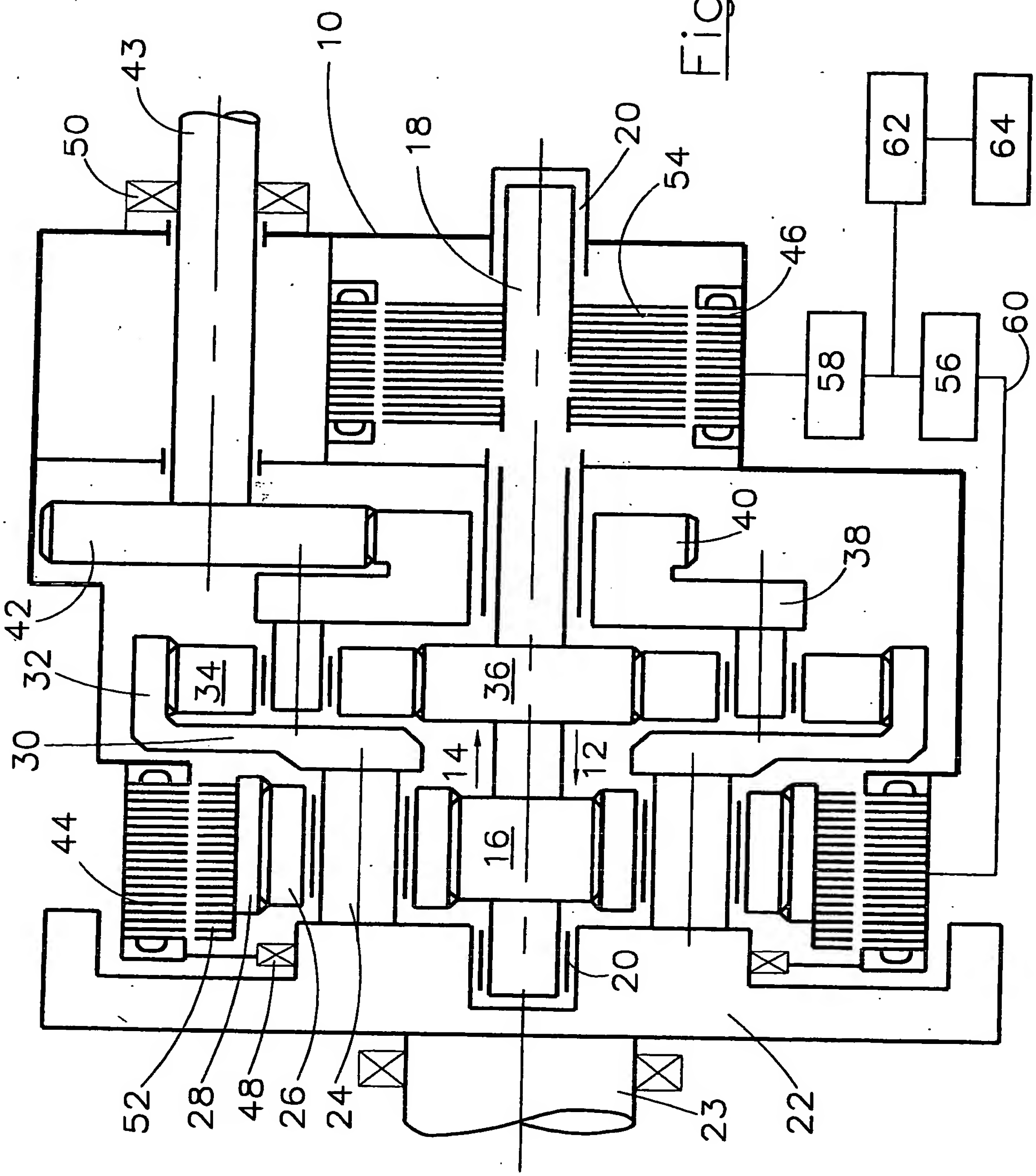
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Fig 1

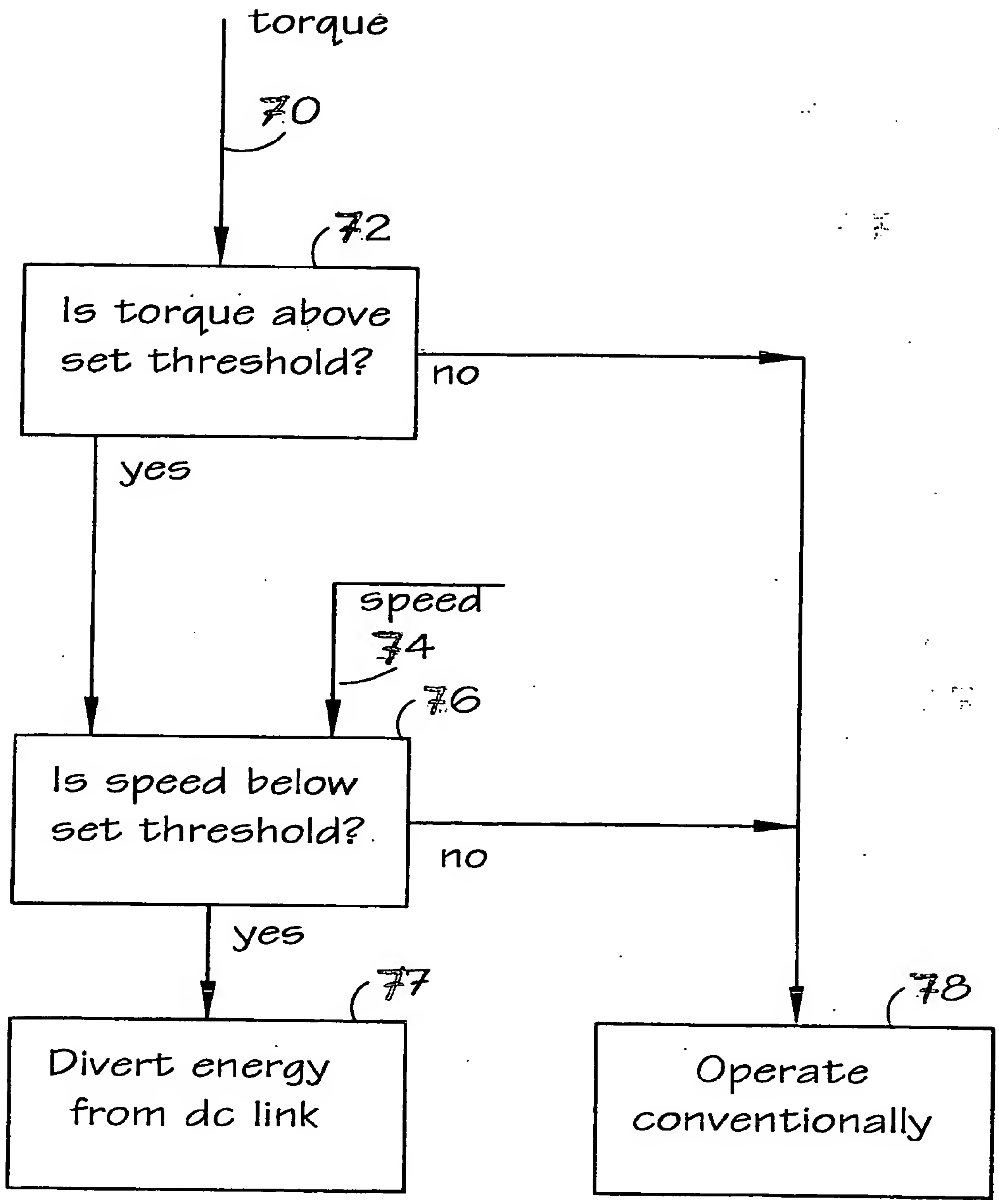
torque
70
72
Is torque above set threshold?
no
yes
speed
74
76
Is speed below set threshold?
no
yes
77
78
Divert energy from dc link
Operate conventionally

Fig 2